CHEMICAL PROFILE OF THE ROSS ICE SHELF AT LITTLE AMERICA V, ANTARCTICA

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January 1974

PREPARED FOR
NATIONAL SCIENCE FOUNDATION
GRANTS AG-212 AND AG-394
BY
CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

PREFACE

This report was prepared by Dr. C.C. Langway, Jr., Specialist 4 M.M. Herron, and J.H. Cragin, of the Snow and Ice Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL). Dr. Langway is Chief of the Snow and Ice Branch.

The work was funded by the National Science Foundation, under Grants AG-212 and AG-394.

Private G. Klouda of USA CRREL performed some of the laboratory measurements. S.J. Johnsen of the University of Copenhagen kindly reviewed the manuscript.

This report was technically reviewed by Dr. R.P. Murrmann, Dr. D.M. Anderson and Dr. M. Mellor.

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Introduction

There is renewed interest in the nature and the origin of Antarctic ice shelves (e.g., Ross: Zumberge 1971; Amery: Budd 1966, Morgan 1972; Filchner: Robin, personal communication, 1973). The first ice core ever to be recovered that completely penetrated a floating ice sheet (ice shelf) was obtained near the seaward edge of the Ross Ice Shelf at Little America V (78°10'S, 162°13'W in 1957) (Ragle et al. 1960). Parts of this 255-m-long, 10-cm-diam core have been stored since recovery in coldrooms at USA CRREL at temperatures below –20°C.

Assuming steady state conditions, Crary et al. (1962) estimated that the bottom ice at Little America V may have originated about 340 km from Little America V, about 20 km inland from the grounding line, and that its maximum age was about 4500 years. They postulated that only the bottom 20 m of ice at Little America V originated inland in West Antarctica. Some physical property studies and electrolytic conductivity measurements were made on the ice core at Little America V by Gow (1968a, 1968b). Dansgaard et al. (1973) recently completed an investigation of the variations in the stable isotopic composition of the core. This report presents results of a study of the Na^+, K^+, Mg^{2+}, and Ca^{2+} concentrations found in the Little America V ice core.

Sample Preparation and Analytical Methods

All laboratory work was performed in a laminar-flow clean air station; workers wore powder-free polyethylene gloves. Core samples 10 to 23 cm long were selected and spaced over the entire depth profile below the firn-ice transition at 52 m. The core above 250 m was obtained in a "dry-hole" (i.e., without the use of drilling fluids), and samples were prepared for chemical analysis by the "dry" cleaning procedure (Herron et al. in prep) to remove surface contaminants resulting from drilling and field core processing. The samples from below 250 m were exposed to drilling fluids and were prepared for chemical analysis by the "wet" cleaning procedure (Herron et al. in prep), which involved alternate rinsings with electronic grade acetone and distilled deionized water. Both groups of solid samples were then melted in precleaned polyethylene containers in a microwave oven and aliquots were taken for analysis. Measurements were made directly on the meltwater using atomic absorption. Samples and standards were analyzed in triplicate with average standard deviations in μg/1 of: Na^+, 1.2; K^+, 0.6; Mg^{2+}, 0.3; and Ca^{2+}, 0.7.

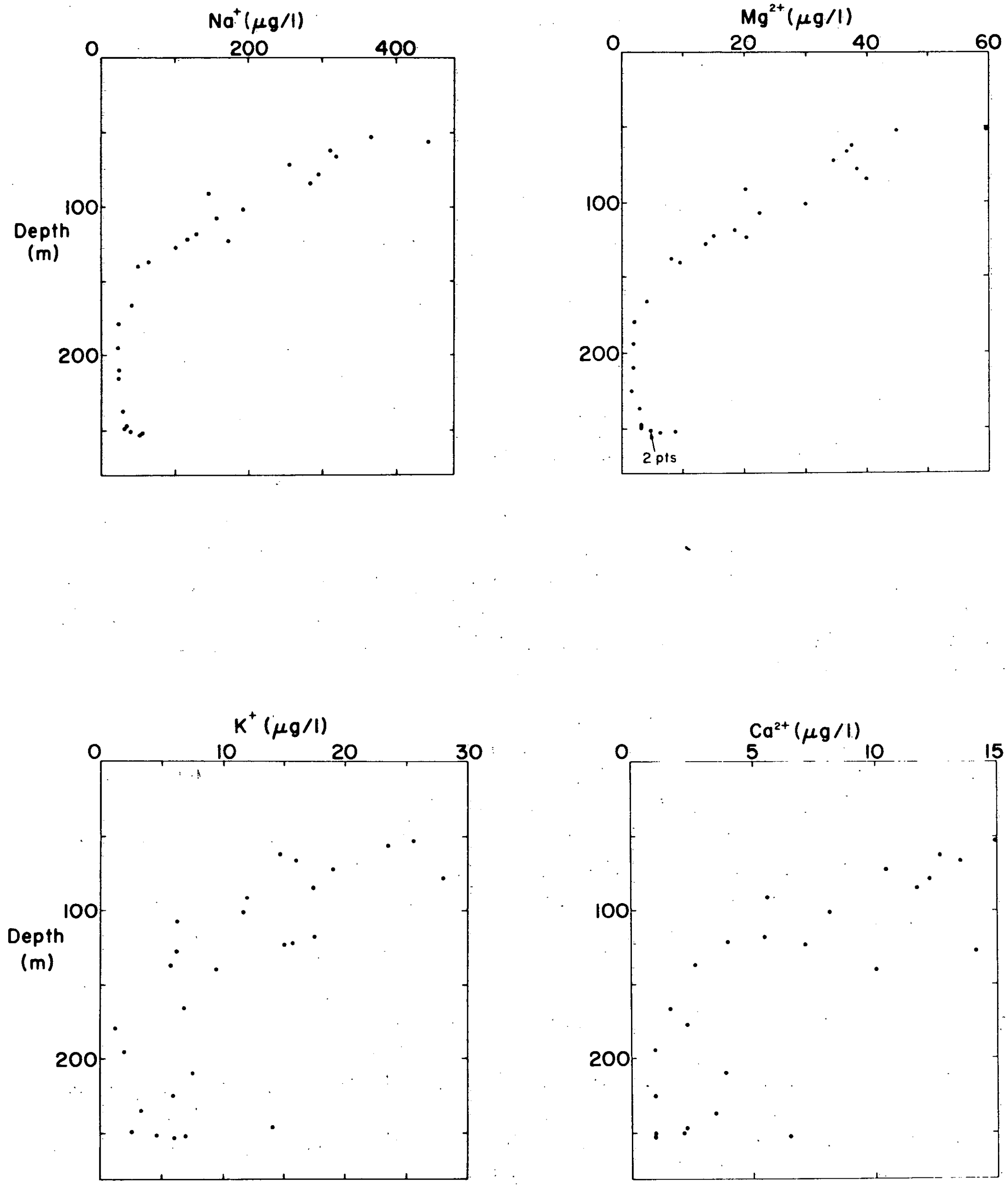

Figure 1. Concentration profile of Na^{+}, Mg^{2+}, K^{+} and Ca^{2+} in the Little America V ice core.

Results and Discussion

The results of the measurements are presented in Figure 1. Table I lists averages of these data and Na/K, Na/Mg and Na/Ca ratios. All cationic concentrations decrease sharply from the 52-m depth to somewhere between 125 m and 150 m. From approximately the 150-m to the 250-m depths, the cationic concentrations appear relatively constant. A slight increase in all of the constituents measured appears below 250 m.

Table I. Average cationic concentrations in ice core samples from Little America V and Byrd Station, Antarctica.

Depth (m)	Na^+	K^+	Mg^{2+}	Ca^{2+}	*Na/K*	*Na/Mg*	*Na/Ca*
52- 84 (7)*	325 ± 62**	21 ± 6	42 ± 9	13 ± 2	16 ± 4	7.8 ± 0.6	24 ± 1
90-123 (6)	152 ± 28	13 ± 4	21 ± 5	6 ± 2	13 ± 7	7.3 ± 0.8	25 ± 3
126-150 (3)	78 ± 20	7 ± 2	10 ± 3	9 ± 6	12 ± 4	7.6 ± 0.4	13 ± 10
150-250 (8)	29 ± 7	5.4 ± 4.1	2.6 ± 0.9	2.2 ± 1.0	9 ± 6	11.6 ± 1.7	13 ± 7
250-255 (4)	48 ± 8	5 ± 2	6.2 ± 1.9	2.6 ± 2.7	10 ± 3	8 ± 1	8 ± 2
Byrd Station core avg†	28 ± 11	3.5 ± 1.9	2.4 ± 1.0	3.2 ± 2.5	9.3 ± 2.4	12 ± 3	5.6 ± 2.1
Seawater					27	8	28

*Number in parentheses is the number of samples analyzed for Na^+, K^+ and Mg^{2+} over the stated depth interval. For Ca^{2+} one less sample was analyzed in each of the 52-84, 90-123, and 250-255-m depths, resulting in a total of 25 samples.
†Average of five samples deposited between 11,800 and 2,500 BP from the Byrd Station deep ice core (Cragin et al. in prep).
**Deviations represent a measure of dispersion of the concentrations for the number of samples measured and are not an indication of precision.

Since deposited snow follows the "law of superposition" (i.e., younger layers overlie older layers), it is evident that the deeper shelf ice is older than the upper shelf ice and originated further upstream along a flowline. The differences in cationic concentrations between the ice above 125 m and that below 150 m indicate that the upper ice originated on the shelf itself and that the lower ice originated inland from the grounding line in a different environmental regime. The reported flowline of ice from West Antarctica to Little America V runs parallel to the West Antarctic coast until it passes the grounding line and then moves toward the seaward edge of the shelf (Hughes 1972). Thus, the lower ice could have been deposited at a rather constant distance from the coast; this explains the uniform composition of the 150-m to 250-m section of the core.

As shown in Table I, concentration levels and ratios in the lower portion of the core are quite close to those found in recent deposits from the Byrd Station, West Antarctica area (Cragin et al. in prep), which is more than 700 km from Little America V. This suggests that the lower ice in the Little America V core originated in an environmental regime similar to that in West Antarctica. The ratios of Na/K, Na/Mg and Na/Ca for the upper portion of the Little America V core approach those of seawater, reflecting the proximity of the open Ross Sea. The Na/K and Na/Ca ratios decrease with depth; this may indicate a geochemical enrichment of K^+ and Ca^{2+} relative to Na^+ that becomes more pronounced in deposits greater distances from the coast (Chesselet et al. 1972, Boutron et al. 1972). The low silicon concentration (0.8 μg/l) found in West Antarctica (Murozumi et al. 1969) suggests that the contribution of terrestrial dust to Marie Byrd Land is negligible.

The above interpretation is in accord with a possible interpretation of the profile of the stable isotopic composition of the core by Dansgaard et al. (in prep). Also, Gow (1970) found an abrupt change in ice texture and fabric in the core at about 150 m which he suggested may be due to a transition from shelf- to inland-derived ice. The slight apparent increase below 250 m in all constituents measured cannot be entirely due to diffusion of ions from the seawater below (Jellinek, personal communication, 1973). In addition, the concentration levels in the bottom 5 m of the core are too low to indicate seawater accretion and, in fact, physical and temperature gradient considerations indicate that appreciable melting of the bottom of the ice occurs at Little America V (Crary et al. 1962). Furthermore, stable oxygen isotopic measurements confirm that the core is composed entirely of glacial ice (Dansgaard et al. in prep).

In the absence of supporting chemical data along the proposed flowline, another interpretation of the data must be considered. Concentrations of sea salt constituents in precipitation generally decrease with increasing distance from the coast until a stable concentration plateau is reached (Junge 1963). In general, the greater the distance of this plateau from the coast the lower the plateau concentration. Such a plateau was found to exist at distances of 600 km to 900 km from the coast in East Antarctica, with average plateau sodium concentrations of 23 μg/l (Boutron et al. 1972). This compares favorably with the average sodium concentration of 27 μg/l in the approximately 150-m to 250-m section of the Little America V core. No corresponding traverse data exist for West Antarctica; but, if a similar phenomenon exists there, the relative constancy of the concentrations in the 150-m to 250-m portion of the core suggests that this mass of ice may have originated more than 600 km inland from Little America V.

Conclusions

Our results suggest that more than the lower 20 m of the Ross Ice Shelf at Little America V must have originated inland from the grounding line. We are led to believe that flow conditions in West Antarctica have not existed in a steady state for the last several thousand years. If the lower ice originated 600 km from Little America V instead of the calculated 340 km (Crary, et al. 1962), flow rates may have been much higher in the recent past than at present and the age of the bottom ice may be much less than the calculated 4500 years. Johnsen et al. (1972) reported an apparent decrease in surface altitude at Byrd Station, with a greatly negative mass budget lasting from 4000 BP to 2500 BP. The accompanying increased ice flow rates would probably bring ice from further inland to Little America V. A more definitive analysis of the recent history of the Ross Ice Shelf depends upon additional cores and surface samples from various geographical areas of West Antarctica.

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire 03755	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

CHEMICAL PROFILE OF THE ROSS ICE SHELF AT LITTLE AMERICA V, ANTARCTICA

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

C.C. Langway, Jr., M. Herron and J.H. Cragin

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1974	9	17

8a. CONTRACT OR GRANT NO. AG-212 and AG-394 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Research Report 316 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY National Science Foundation Washington, D.C.

13. ABSTRACT

Measurements of the concentrations of Na^{+}, K^{+}, Mg^{2+}, and Ca^{2+} were made on 28 samples from the 255-m-deep ice core from Little America V. All concentrations decrease sharply with depth from the firn-ice transition at 52 m to somewhere between 125 m and 150 m. From 150 m to 250 m the cationic concentrations are relatively constant. This is interpreted to indicate that the ice above 125 m fell as snow on the Ross Ice Shelf and that ice below 150 m originated inland on Marie Byrd Land.

14. Key Words

Antarctica
Chemical properties
Geochemistry
Geochronology
Ionic concentrations

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